CHANGES IN TKA KINEMATICS AND CONTACT FORCES INDUCED BY MAL-CONFIGURATIONS: A NUMERICAL STUDY

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Introduction

Total Knee Arthroplasty (TKA) is a very successful surgical procedure, but patients with difficulties or pain during motion still persist. TKA patient outcomes can be affected not only by implant design, but also by implant position and by patient-related anatomical factors. To check how and how much the influence of these factors can alter both tibio-femoral (TF) kinematics and TF and patello-femoral (PF) contact forces, a numerical analysis was performed on several TKA designs during squatting.

Methods

Physiological bone models were obtained from a CT of a cadaver leg and the physiological soft issue insertion points were localized according to literature [Innocenti, 2011; Victor, 2009a]. Four TKA designs were implanted according to their surgical guidelines in the physiological model: a conventional fixed bearing design; a high flex fixed bearing design; a mobile bearing design; a hinge prosthesis design).

The following configurations were analyzed [Innocenti, 2011]: 1. the theoretical configuration, corresponding to the surgical guideline technique, and physiological locations of the soft tissue insertion points; 2. a change in position of the tibial component in medio-lateral (ML) and antero-posterior (AP) directions; 3. a change in orientation of the tibial component in flexion-extension (FE), abduction-adduction (AA) and internal-external (IE) orientation; 4. patella alta and patella baja; 5. tilting of the patellar component (IE rotation); 6. a change in location of the two collaterals ligaments in ML, AP and proximo-distal (PD) directions.

For each prosthesis and configuration, a squat up to 120° of flexion, with a vertical hip force of 200N, was simulated using LifeMOD/KneeSIM 2007.0.5 (LifeModeler, Inc., San Clemente, CA) following the same procedure as described in experimental tests [Victor, 2009b]. TF kinematics along IE, AA and AP axes and TF and PF maximal contact forces are observed and compared for all the 98 configurations in analysis.

Results

The frequency with which deviations from the reference kinematics occur due to tibial component malpositioning, patellar malpositioning and the soft-tissues anatomy are listed in Table 1. We discriminated between three levels of deviation, referring to the reference configuration, in terms of TF kinematics (2°, 3° and 4° or 2 mm, 3 mm and 4 mm) and contact forces (10%, 20% and 30%).

	Tibial component	Patellar component	Collateral ligaments
Difference in IE rotation ≥ 2°	11	1	11
Difference in IE rotation ≥ 3°	2	1	6
Difference in IE rotation ≥ 4°	1	1	4
Difference in AA tilting ≥ 2°	5	0	1
Difference in AA tilting ≥ 3°	4	0	0
Difference in AA tilting > 4°	1	0	0
Difference in AP translation ≥ 2 mm	10	0	0
Difference in AP translation ≥ 3 mm	2	0	0
Difference in AP translation ≥ 4 mm	0	0	0
PF contact force ≥10%	6	12	0
PF contact force ≥ 20%	3	6	0
PF contact force ≥ 30%	2	3	0
Medial TF contact force ≥10%	7	7	12
Medial TF contact force ≥ 20%	4	2	9
Medial TF contact force ≥ 30%	4	0	2
Lateral TF contact force ≥10%	4	4	14
Lateral TF contact force ≥ 20%	1	0	9
Lateral TF contact force ≥ 30%	0	0	4

Table 1: The table shows the frequency [%] of affected configurations, with respect to the total number of analyzed mal-configurations.

Discussion

In this project the effects of tibial mal-positioning, patellar mal-positioning and soft-tissues anatomies on knee kinematics and kinetics were numerically analyzed and correlated for different TKA designs.

The used model has been validated both for the contact force analysis [Innocenti, 2011] and for the kinematics analysis [D'Lima, 2011; Nakamura, 2010; Victor, 2009b]. Deviations in kinematics are usually quite small (smaller than 5° or 4 mm), thus proportional to the applied changes in alignment, while changes in contact forces can reach much higher values [Innocenti, 2011]. The same small changes in configuration which lead to the small changes in kinematics, can cause dramatic differences in contact forces. This finding has important clinical implications: a relatively small surgical errors, which may not be detectable using standard follow-up tools used by clinicians, can still lead to considerable differences in pressures and their distributions, strains in ligaments and, as a consequence, pain.

References

D'Lima *et al*, Clin Orthop 469:2953–2970 2011.
Innocenti *et al,* J Biomech, 44:1573-1581, 2011.
Nakamura *et al*, JoA 25:3, 2010
Victor *et al*, The Knee, 16:358-65, 2009a.
Victor *et al,* JBJS*Am.* 91:150-163, 2009b.